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Indian Standard

CODE OF PRACTICE FOR MAINTENANCE AND TESTING OF LARGE LEAD ACID BATTERIES FOR GENERATING STATIONS AND SUBSTATIONS

ICS 19.080 ; 29.220.20

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

May 2000 **Price Group 3**

Secondary Cells and Batteries Sectional Committee, ET 11

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Secondary Cells and Batteries Sectional Committee had been approved by the Electrotechnical Division Council.

This standard covers the requirements of maintenance and testing of large lead acid batteries for generating stations and substations.

While preparing this standard, assistance has been derived from IEEE 450-1987 'Recommended practice for maintenance and testing of large lead storage batteries for generating stations and substations'.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CODE OF PRACTICE FOR MAINTENANCE AND TESTING OF LARGE LEAD ACID BATTERIES FOR GENERATING STATIONS AND SUBSTATIONS

1 SCOPE

This standard furnishes the recommended practice for maintenance and testing that can be used to optimize the life and performance of lead acid batteries.

2 TERMINOLOGY

Following definitions shall apply to this standard.

2.1 Battery Duty Cycle

The load currents, a battery is expected to supply for specific time period.

2.2 Cell Size

The rated capacity of a lead acid storage cell and number of plates in the cell.

2.3 Full Float Operation

Operation of a dc system with the battery, battery charger and load all connected in parallel and with the battery charger supplying the dc load and self discharge or charging current or both required by battery. The battery will deliver current only when:

a) main ac supply is lost, and
b) load on dc system exceeds the maximum output of the battery charger.

2.4 Rated Capacity

The ampere hour capacity assigned to a lead acid storage cell by its manufacturer for a given discharge time, at a specified temperature.

2.5 Battery Rack

A structure used to support a group of cells.

2.6 Acceptance Test

A constant current capacity test made on a new battery to determine that it meets specifications or manufacturer's ratings.

2.7 Capacity Test

A discharge of a battery to designated terminal voltage (end voltage).

2.8 Performance Test

A constant current capacity test made on a battery, as found after being in use/service, to detect any change in the capacity determined by the acceptance test.

2.9 Service Test

A special test of battery's ability to satisfy the design requirements of the dc system.

2.10 Terminal Connection Detail

Connections made between rows of cells or at the positive and negative terminal of the battery, which may include the lead plated terminal plates, cables with lead plated lugs and lead plated rigid copper connectors.

3 MAINTENANCE

3.1 General

Proper maintenance of lead acid batteries will prolong the life of the battery and will aid in assuring that it is capable of satisfying its design requirements. A good battery maintenance programme will serve as a valuable aid in determining the need for battery replacement. Station battery maintenance should be performed by personnel knowledgeable of batteries and the safety precautions involved.

3.2 Safety

The following safety precautions should be followed in station battery maintenance. Work performed on batteries should be done only with the proper and safe tools and with appropriate protective equipments.

3.2.1 *Methods*

Work performed on a battery in service should use methods to preclude circuit interruption or arcing in the vicinity of the battery.

3.2.2 *Protective Equipment*

a) Goggles,
b) Acid resistant gloves,
c) Protective aprons,
d) Portable or stationary water facilities for rinsing eyes and skin in case of acid spillage, and

e) Bicarbonate of soda or other suitable neutralizing agent recommended by the manufacturer for acid spillage.

3.2.3 *Precautions*

The following protective procedures should be observed during maintenance:

a) Insulate the handles of tools used for tightening connector bolts,

b) Prohibit arcing, smoking, and an open flame in the immediate vicinity of the battery,

c) Ensure that test leads are connected with sufficient length of cable to prevent accidental arcing in the vicinity of the battery,

d) All connections to load test equipment should include short circuit protection,

e) Ensure that battery area ventillation is operable, and

f) Ensure unobstructed egress from the battery area.

3.3 Inspections

All inspections should be made under normal float conditions. Specific gravity readings are not accurate during charge or following the addition of water. Readings should be taken in accordance with the manufacturer's instruction. The following factors should be carefully taken into account during inspection and use/maintenance of batteries.

3.3.1 *General*

Inspection of the battery on a regularly scheduled basis (at least once per month) should include a check and record of the following:

a) General appearance and cleanliness of the battery and battery area,

b) Charger output current and voltage,

c) Electrolyte levels,

d) Any cracks in cells or leakage of electrolyte,

e) Any evidence of corrosion at either terminals or connectors, and

f) Ambient temperature and condition of ventillation equipment.

3.3.2 *Quarterly Inspection*

At least once per quarter a general inspection should be augmented as follows:

Check and record:

a) Specific gravity of each cell;

b) Voltage of each cell and total battery terminal voltage; and

c) Temperature of electrolyte a representative cells (suggestion: take temperature in cells number 6, 12, 18, 24...........).

3.3.3 *Yearly Inspection*

At least once each year a quarterly inspection should be augmented as follows:

Check and record:

a) Cell condition (This would involve a detailed visual inspection of each cell in addition to the general inspection in **3.3.1**). Review manufacturers recommendations;

b) Tightness of bolted connections to manufacturer's recommended torque value followed by cell to cell and terminal connection detail resistance;

c) Integrity of battery racks; and

d) Performance test (**6.4**).

3.3.4 *Special Inspections*

If the battery has experienced an abnormal condition (such as a severe discharge or overcharge) an inspection should be made to ensure that battery has not been damaged. Also include the requirements of **3.3.2**.

3.4 Corrective Action

3.4.1 The following items indicate the conditions that can be easily corrected prior to next general inspection:

a) When any cell electrolyte reaches the low level line, water should be added to bring all cells to the high level line. Water quality should be in accordance with manufacturer's instructions.

b) When any intercell connection or terminal connection detail resistance value exceeds its installation value by more than 20 percent, disassemble, clean, reassemble and retest it.

c) When cell temperature deviates more than 3°C from each other during a single inspection, determine the cause and correct.

d) When excessive dirt is noted on cells or connectors, wipe with water-moistened clean wiper. Remove electrolyte spillage on cell covers and containers with a bicarbonate of soda or other suitable neutralizing agent and water-moistened wiper. All wipers used should be free of oil distillates.

e) When the float voltage measured at the battery terminals is outside its recommended operating range, it should be adjusted.

3.4.2 The above items indicate conditions that, if allowed to persist for extended periods, can reduce the life of battery. They do not necessarily indicate a loss of battery capacity. Therefore, corrective actions can be accomplished prior to the next quarterly inspection, provided that the battery condition is monitored at regular intervals (not to exceed one week). An equalizing charge normally requires an equalizing voltage be applied continuously for 35 to 70 h or longer (refer to manufacturer's instructions).

a) An equalizing charge should be given if the specific gravity, corrected for temperature and electrolyte level, of an individual cell is more than 10 points (0.010) below the average of all cells at the time of inspection.

b) An equalizing charge should be given if the average specific gravity, corrected for temperature and electrolyte level of all cells drops more than 10 points (0.010) from average installation value.

3.4.3 An equalizing charge should be given immediately if any cell voltage is below 2.13 V while floating at the time of inspection.

If the above conditions did not occur and the equalizing charge was not given, even then, an equalizing charge should be given to the battery at least once in 18 months. This equalizing charge can be waived for certain batteries based on an analysis of the records of operation and maintenance inspections.

3.4.4 *Other Abnormalities*

Correct any other abnormal conditions noted.

3.5 State of Charge

State of charge is normally indicated by specific gravity readings. However, specific gravity readings may not be accurate when battery is on charge following a discharge or following the addition of water. When cell design permits, specific gravity reading accuracy can be improved by averaging several readings taken at different levels within a cell. A more accurate indicator of return to full charge is a stabilized charging or float current.

4 EFFECT OF VARIOUS PARAMETERS AND CORRECTIVE ACTIONS

4.1 Specific Gravity

4.1.1 *Effect of Charging*

During the recharge of battery, high specific gravity sulphuric acid is generated. This acid will sink towards to bottom of the cell resulting in a specific gravity gradient which produces an incorrect low reading at top of the cell. Therefore it is normal for the state of charge, as indicated by the specific gravity at the top of the cell, to lag behind that indicated by the ampere-hours of recharge current. Charging voltage limits do not ordinarily allow enough recharging current to provide mixing action, therefore this gradient may persist until corrected by diffusion. To determine the correct reading of specific gravity (in other words, the correct state of charge of battery) it is recommended to make the specific gravity readings at top, middle and bottom of the cell. The average of these three readings will accurately relate the state of charge to the full charge specific gravity specified by the manufacturer.

4.1.2 *Effect of Temperature*

The specific gravity readings are based on a design ambient temperature of 27°C. The readings must be corrected for actual electrolyte temperature and level. Clause **11.4** of IS 8320 shall be referred for the applicable temperature correction factor for specific gravity. The specific gravity of the electrolyte in a cell will increase with a loss of water due to electrolysis or evaporation. When specific gravity readings are being taken the electrolyte levels should also be measured and recorded. The battery manufacturer will provide a gravity correction factor for the particular cells involved. The electrolyte level readings should be taken only after the battery has been at a float voltage for at least 72 h.

4.1.3 *Effect of Water Addition*

When water is added to a cell, it tends to float on top of the electrolyte because its specific gravity is 1.000 in comparison to 1.215 nominal for the electrolyte in most batteries. If the cells are on float charge condition, there is very little mixing of the electrolyte due to gassing. It may take 6 to 8 weeks or longer for complete mixing to occcur. The specific gravity should be read before adding water or battery should be given an equalizing charge after the water is added. The battery should be back on normal float voltage for 72 h before specific gravity is measured after an equalizing charge.

4.2 Float Voltage

4.2.1 *Low Voltage Cells*

Cell voltage is not, by itself, an indication of the state of charge of the battery. Prolonged operation of cells below 2.13 V can reduce the expected life of the cells. To obtain the normal life, these cells should be given an equalizing charge. A cell voltage of 2.07 V or below under float conditions and not caused by elevated temperature of the cell, indicate internal cell problem and may require cell replacement.

4.2.2 *High Voltage Cells*

There is no detrimental effect associated with a cell that has a float voltage higher than the average of other cells in the battery except for the extreme case where the cell potential equals or exceeds the gassing potential (2.38V at 27° C). If an equalizing charge is given to the battery, the float voltage of the other cells will increase and float current will be decreased. This decrease will lower the voltage of the higher cell.

4.2.3 *Effect of Temperature*

As the temperature of the electrolyte increases, resistivity decrease and charging current increases in order to maintain a constant cell voltage. Therefore cells in a battery at a higher temperature than others will require higher current. The voltage of warmer cells will be lower than the average. If a warmer cell is below 2.13 V its voltage can be corrected for temperature by adding 0.005 V per °C that the cell temperature is above the average temperature of the other cells. If the cell voltage is less than 2.13 V after being corrected for the effect of temperature, an equalizing charge should be made to eliminate the cause of the temperature differential.

When all cells are at same higher temperature, the charging current under normal float conditions will automatically increase to hold the required float voltage. However, individual cell voltages will not be affected and no correction for temperature will be necessary.

4.3 Determining the State of Charge When a Specific Gravity Gradient Exists

When the cell is designed so that specific gravity readings can be made at the top, middle, and bottom of the cell, the average of these three readings will accurately relate the state of charge to the full-charge specific gravity specified by the manufacturer.

The pattern of charging current delivered by a conventional voltage-regulated charger after a discharge provides another method for determining the state of charge. As the cells approach full charge, the battery voltage rises to approach the charger output voltage, and the charging current decreases. When the charging current has stabilized at the charging voltages, the battery is charged, even though specific gravities have not stabilized.

If the charging voltage has been set at a value higher than normal float voltage (so as to reduce charging time), it is normal practice to reduce the charging voltage to a float value after the charging current stabilizes. The float current will soon stabilize even though the top level specific gravity readings continue to increase.

NOTE — Refer to the manufacturer's instructions for time periods to maintain charging voltages after current stabilization.

4.4 Urgency of Corrective Actions

4.4.1 *Adding Water*

The addition of water is required when the top of separator guard is exposed and the electrolyte level should be maintained within the high level line.

4.4.2 *Connection Resistance*

Intercell and terminal connection details resistance measurements which are more than 20 percent above the installation resistance values are cause for concern and should be corrected prior to next general inspection. The timing of the corrective action should be determined by an analysis of the effect of the increased resistance.

4.4.3 *Cell Temperature*

Large cell-temperature deviations are usually caused by shorting conditions, which are also evident by the cell voltage. This is cause for immediate cell replacement. All other temperature deviations are usually caused by outside conditions that are part of the installation. While operation at elevated temperatures will reduce life expectancy, it will not adversely affect capacity.

4.4.4 *Equalizing Charge*

In general, the need for initiating an equalizing charge is not critical. However, a deviation in the specific gravity of more than 10 points that is 0.010 is a cause for concern and should be analyzed for its effect on battery capability. The need for an equalizing charge and any corrective action is directly proportional to the deviation. When average specific gravity of the battery drops more than 10 points (0.010) from acceptance test value, the charge should be as high as permissible (within dc system design limits).

When an individual cell voltage during floating corrected for temperature is below 2.13 V during floating, corrective action should be initiated immediately. It can be accomplished by providing an equalizing charge to the entire battery. However, it is often more convenient to apply the equalizing charge to the individual cell.

5 CAPACITY TEST SCHEDULE

5.1 The following schedule of capacity tests is used to :

a) determine whether the battery meet its specification or the manufacturer's rating, or both;

b) periodically determine whether the rating of the battery, as found, is holding up; and

c) if required, determine whether the battery meet the design requirements of the system to which it is connected.

5.1.1 *Acceptance*

An acceptance test of the battery capacity (*see* **6.4**) should be made either at the factory or upon initial installation as determined by the user. The test should meet a specific discharge rate and duration relating to the manufacturer's rating or to the purchase specification's requirements.

NOTE — Batteries may have less than rated capacity when delivered. Unless 100 percent capacity upon delivery is specified, initial capacity can be as low as 85 percent of rated. This will rise to rated capacity in normal service after several years of float operation.

5.2 Performance

5.2.1 A performance test of the battery capacity (*see* **6.4**) should be made within the first 2 years of service. Initial conditions shall be as described in **6.1**, omitting requirements (a) and (b). Results of this test reflect all factors, including maintenance, that determine the battery capability. It is desirable for comparison purposes that the performance tests be similar in duration to the battery acceptance test (*see* **5.1**). If on a performance test the battery does not deliver its expected capacity, the test should be repeated after the requirements of **6.1**(a) and (b). Results of this test reflect all factors, including maintenanoe, that determine the battery capability.

5.2.2 Additional performance tests should be given to each battery at 5 year intervals until it shows signs of degradation as outlined in **5.2.3**.

5.2.3 Annual performance tests of battery capacity should be given to any battery that shows signs of degradation or has reached 85 percent of the service life expected for the application. Degradation is indicated when the battery capacity drops more than 10 percent of rated capacity from its average on previous performance tests, or is below 90 percent of the manufacturer's rating.

5.3 Service

A service test of the battery capability (*see* **6.6**) may be required by the user to meet a specific application requirement upon completion of the installation. This is a test of the battery's ability to satisfy the design requirements (battery duty cycle) of the dc system. This test is performed for class 1E nuclear power generating station batteries as part of the preoperational and periodic dc system tests. If the system design changes, sizing will have to be reviewed, and the service test may have to be repeated.

6 PROCEDURE FOR BATTERY CAPACITY TESTS

This procedure describes the recommended practice of capacity testing by discharging the battery. All testing should follow the safety requirements listed in **3.2**.

6.1 Initial Conditions

The following list gives the initial requirements for all battery capacity tests. For performance (*see* **5.2**) and service (*see* **5.3**) tests when the results should reflect maintenance practices, omit requirements (a) and (b) below. The most stringent performance and service test conditions will be just prior to the scheduled equalizing charge (*see* **3.4.3**).

a) Verify that the battery has had an equalizing charge completed more than 3 days and less than 7 days prior to the start of the test,

b) Check all battery connections and make sure that all connectors are clean, tight and free of corrosion,

c) Read and record the specific gravity and float voltage of each cell just prior to the test,

d) Read and record temperature of the battery electrolyte for an average temperature (suggested every sixth cell),

e) Read and record the battery terminal float voltage,

f) Disconnect the charger from the battery, and

g) Take adequate precautions (such as isolating the battery to be tested from other batteries and critical loads) to ensure that a failure will not jeopardize other systems or equipment.

6.2 Test Length

The recommended procedure is to make a capacity test for approximately the same length of time as the critical period for which the battery is sized (*see* **6.6** for duration of the service test).

6.3 Discharge Rate

The discharge rate depends upon the type of test selected. For the acceptance test or performance test, the discharge rate should be a constant current load equal to the manufacturer's rating of the battery for the selected test length. *See* **6.6** for the test discharge rate of the service test.

Note that the test discharge current is equal to the rated discharge current divided by K, where K is discharge current correction factor for the initial electrolyte temperature. Refer applicable Indian Standards.

6.4 Acceptance and Performance Tests

Set up a load with an ammeter and a voltmeter with the provisions that the load be varied to maintain a constant current discharge equal to the rating of the battery at the selected rate (*see* **6.3**).

a) Connect the load to the battery, start the timing, and continue to maintain the selected discharge rate,

b) Maintain the discharge rate until the battery terminal voltage decreases to a value equal to the specified average voltage per cell (usually 1.75V) times the number of cells, and

c) Read and record individual cell voltages and the battery terminal voltage. The readings should be taken while the load is applied at the beginning and the completion of the test and at specified intervals. There should be a minimum of three readings.

NOTE — Individual cell voltages readings should be taken between respective posts of like polarity of adjacent cells, so as to include the voltage drop of the intercell connectors.

d) If an individual cell is approaching reversal of its polarity (plus 1 V or less) but the terminal voltages has not yet reached its test limit, the test should be continued with a jumper across the weak cell. Complete the jumper connection away from the cell to avoid arcing near the cell. The new minimum terminals voltage should be determined based on the remaining cells {(*see* **6.4**(ii)}.

e) Observe the battery for intercell connector heating.

f) At the conclusion of the test, determine the battery capacity according to the procedure outlined in **6.5**.

6.5 Determining Battery Capacity

For an acceptance or performance test, use the following equation to determine the battery capacity:

$$\text{Percent capacity at } 27^\circ\text{C} = \frac{T_a}{T_s} \times 100$$

where

T_a = actual time of test to specified terminal voltage [(*see* **6.4** (ii)], and

T_s = rated time to specified terminal voltage.

6.6 Service Test

A service test is a special battery capacity test which may be required to determine if the battery will meet the design requirements (battery duty cycle) of the dc system (*see* **5.3**). The system designer must establish the test procedure and acceptance criteria prior to the test. Recommended procedure for the test is:

a) The initial conditions shall be as identified in **6.1** [omit items (a) and (b)],

b) The discharge rate and test length should correspond as closely as is practical to the design requirements (battery duty cycle) of the dc system, and

c) If the battery does not meet the design requirements of the dc system, review its rating to see if it is properly sized, equalize the battery, and, if necessary, inspect the battery as discussed in **3.3** and take necessary corrective actions. A battery performance test (*see* **5.2**) may also be required to determine whether the problem is the battery or the application.

6.7 Restoration

Disconnect all test apparatus. Equalize the battery if necessary and return to normal service.

7 BATTERY REPLACEMENT CRITERIA

The recommended practice is to replace the battery if its capacity as determined is below 80 percent of the manufacturer's rating. The timing of the replacement is a function of the sizing criteria utilized and the capacity margin available, compared to the load requirements. Whenever replacement is required, the recommended maximum time for replacement is 1 year. A capacity of 80 percent shows that battery rate of deterioration is increasing even if there is ample capacity to meet the load requirements. Other factor, such as unsatisfactory battery service test result require battery replacement unless a satisfactory service test can be obtained following corrective actions.

Physical conditions such as plate conditions together with age, often determines the case of complete battery or individual cell replacement. Reversal of a cell is also an indicator for further investigations into need for individual cell replacement. Replacement cells, if used, should be compatible with existing cells and should be tested prior to installation. Replacement cells are not usually recommended as the battery nears to its end of life.

Failure to hold a charge, as shown by cell voltage and specific gravity readings, is a good indicator for further investigation into the need for replacement.

8 RECORDS

Data obtained from inspections and corrective actions are important to the operation and life to batteries. Data such as indicated in **5.3** should be recorded at the time of installation and as specified during each inspection. Data records should also contain reports on corrective actions and on capacity and other tests indicating the discharge rates, their duration and results.

It is recommended that forms be prepared to record all data in an orderly fashion and in such a way that comparison with past data is convenient. For a meaningful comparison, all data should be converted to a standard base in accordance with the manufacturer's recommendation.

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BUREAU OF INDIAN STANDARDS

Headquarters :

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002
Telephones : 323 01 31, 323 33 75, 323 94 02

Telegrams : Manaksanstha
(Common to all offices)

Regional Offices :

		Telephone
Central	: Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110 002	323 76 17 323 38 41
Eastern	; 1/14 C. I. T. Scheme VII M, V. I. P. Road, Kankurgachi CALCUTTA 700 054	337 84 99, 337 85 61 337 86 26, 337 91 20
Northern	: SCO 335-336, Sector 34-A, CHANDIGARH 160 022	60 38 43 60 20 25
Southern	: C. I. T. Campus, IV Cross Road, CHENNAI 600 113	235 02 16, 235 04 42 235 15 19, 235 23 15
Western	: Manakalaya, E9 MIDC, Marol, Andheri (East) MUMBAI 400 093	832 92 95, 832 78 58 832 78 91, 832 78 92

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